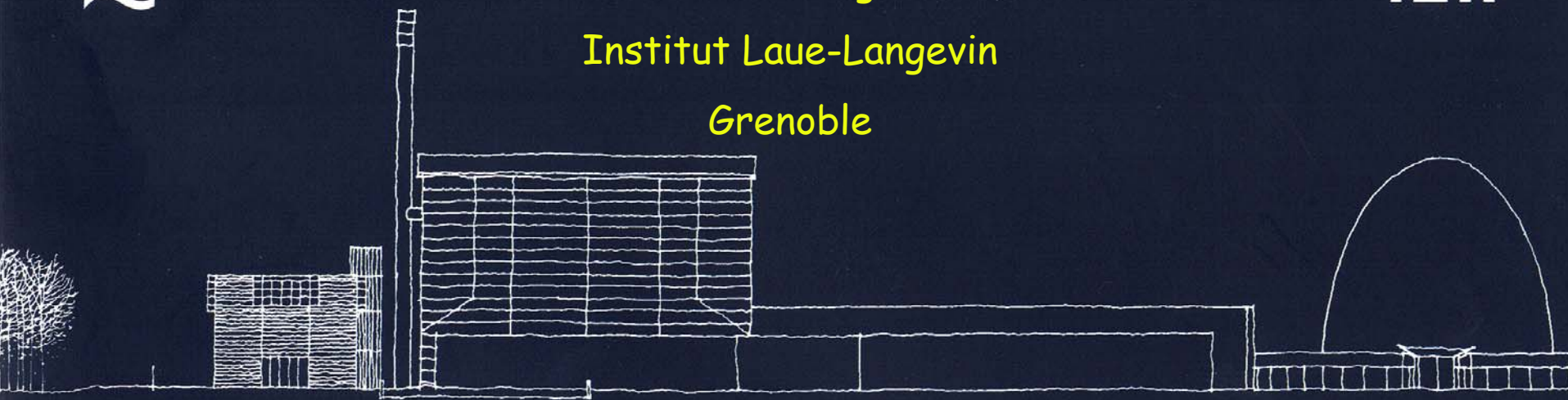
Industrielle Forschung mit Neutronen

Richard Wagner

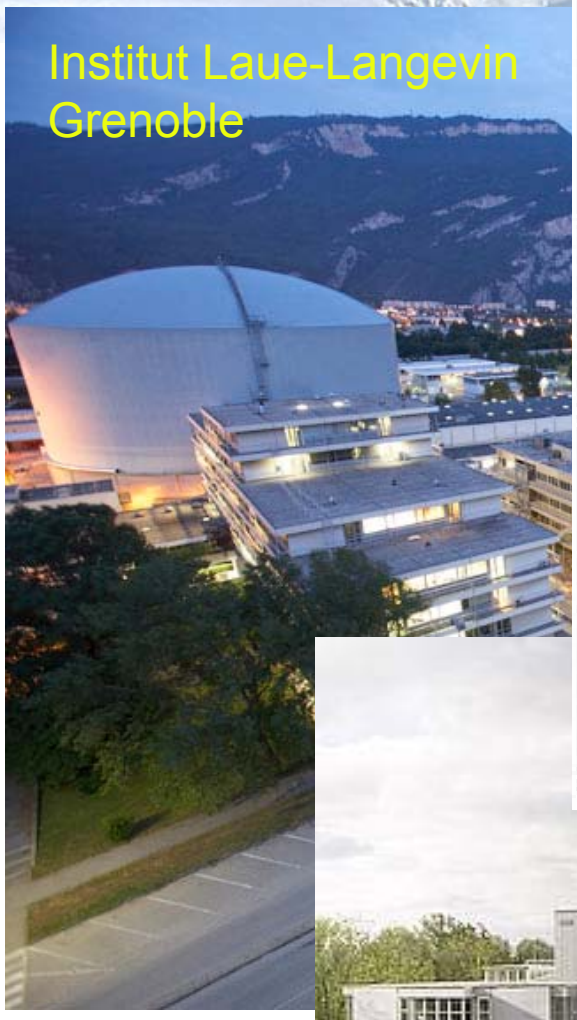
Institut Laue-Langevin

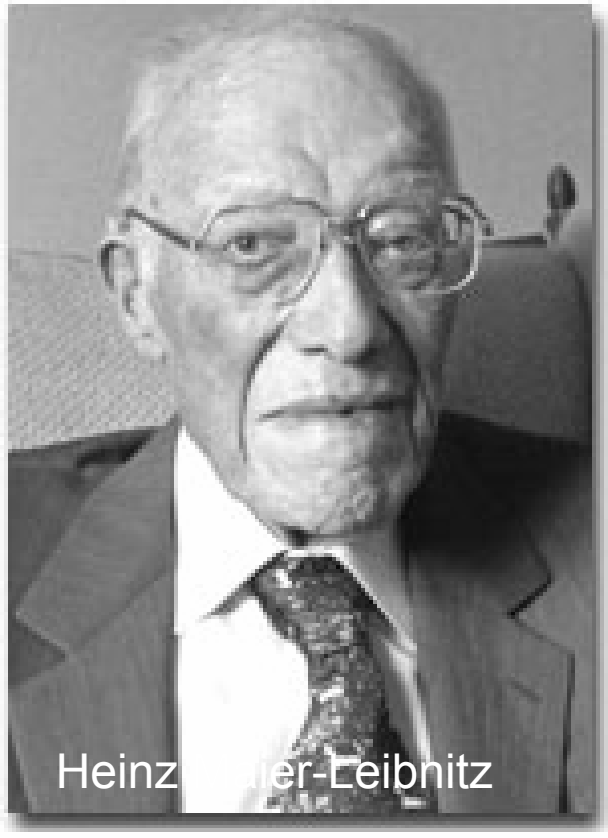
Grenoble



50 Jahre Neutronenforschung in Garching – und deren Zukunft

FRM und ILL: Wissenschaftliche Partner seit 40 Jahren





Forschung mit Neutronen ?

…Grundlagen- oder anwendungsnahe Forschung…?

Dem Anwenden muss das Erkennen vorausgehen!

Max Planck

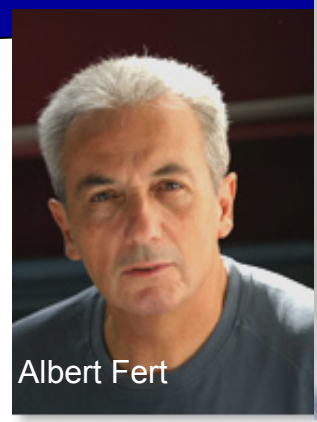
Dem Anwenden muss das Erkennen vorausgehen!

Max Planck

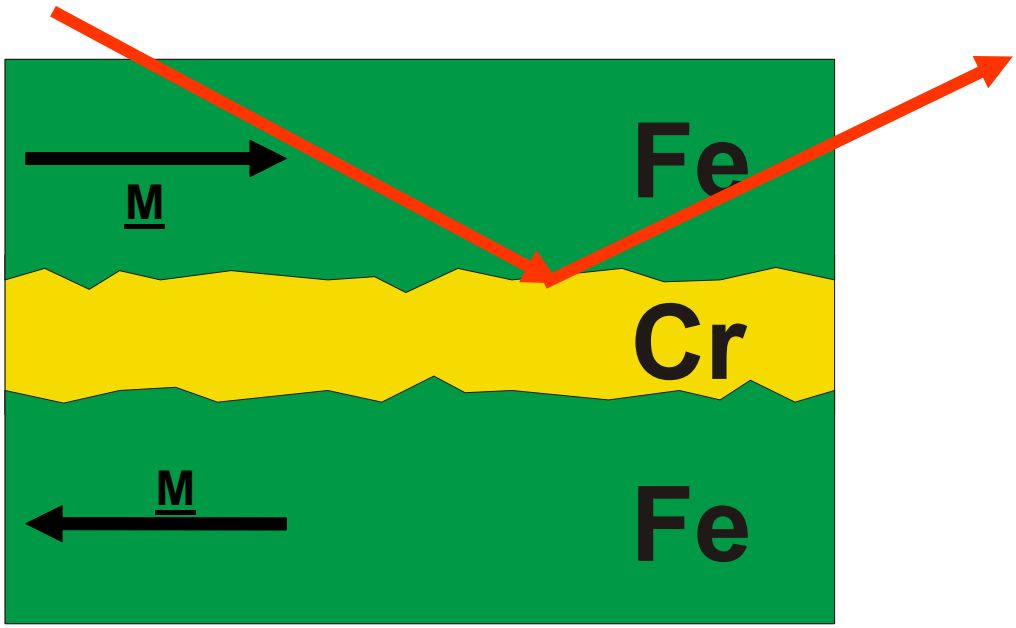
GMR-Effekt

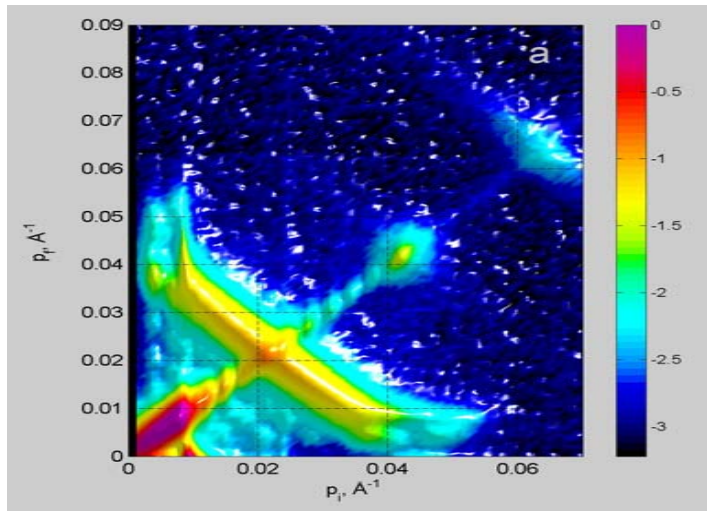
Magnetische Mehrfachschichten

Neutronenreflektometrie


Albert Fert


Peter Gruenberg

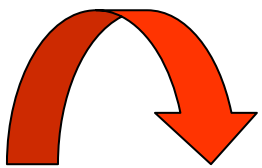




Industrielle Forschung mit Neutronen

Ziele:

- Herstellung von Materialien/Werkstoffen fuer neuartige Anwendungen
- Ersatz von « konventionellen » Materialien
- Entwicklung neuartiger Herstellungstechnologien
- Material- und Qualitaetspruefung



….Materialforschung und –entwicklung !!!

Industrielle Forschung mit Neutronen

NEUTRONS FOR SCIENCE

Motivation:

- optimierte Eigenschaften
- neue Anwendungsfelder
- Energieeinsparung
- Oekologie

- Metalle
- Legierungen
- Keramiken
- Kunststoffe
- Verbundwerkstoffe

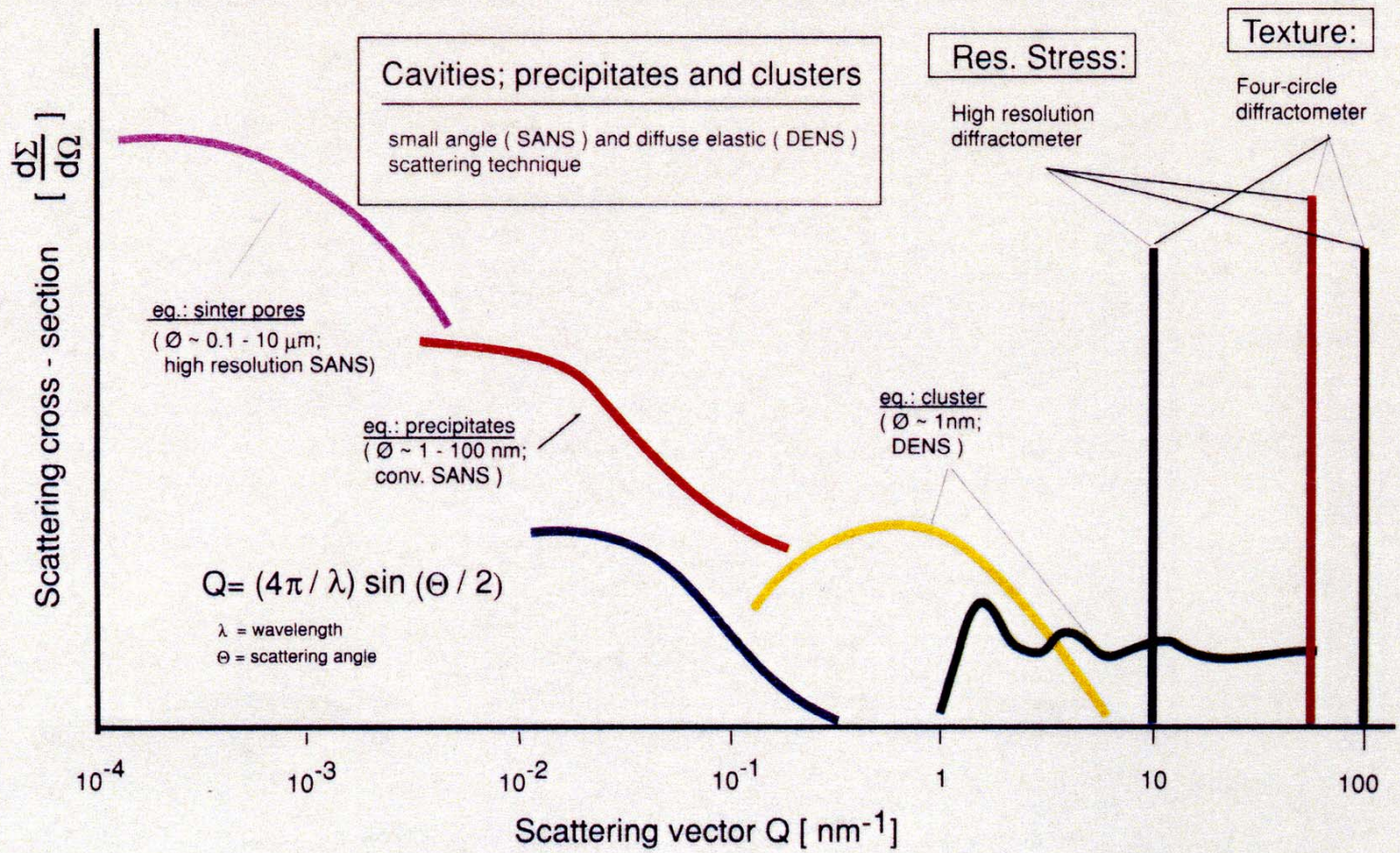
- Magnete
- Schichtsysteme
- Supraleiter
- Halbleiter
- Katalysatoren

Industrielle Forschung mit Neutronen

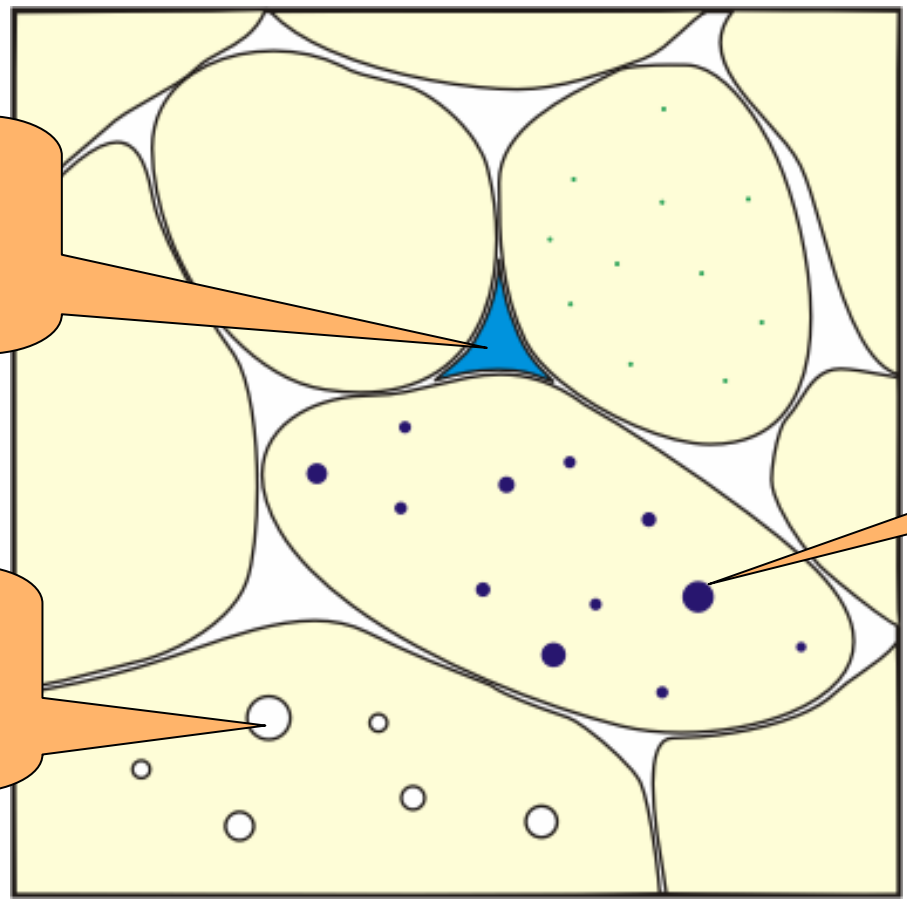
Anwendungsbereiche

- Entwicklung neuer Herstellungsverfahren
- Schaedigungsmechanismen unter Belastung (σ ;ε ; T; Φ)
- Entwicklung/Einstellung von Mikrostrukturen
- Zerstoerungsfreie Werkstoff-/Bauteilpruefung

Schematische Darstellung elastischer n-Streukurven



Entwicklung/Einstellung von Mikrostrukturen



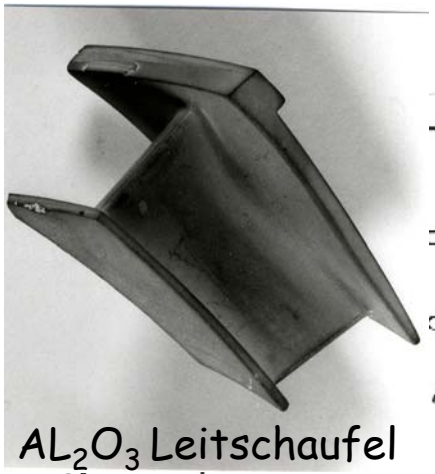
Korngrenzen-segregationen f(c,T,p)

Ausscheidungen f(R,T,t)

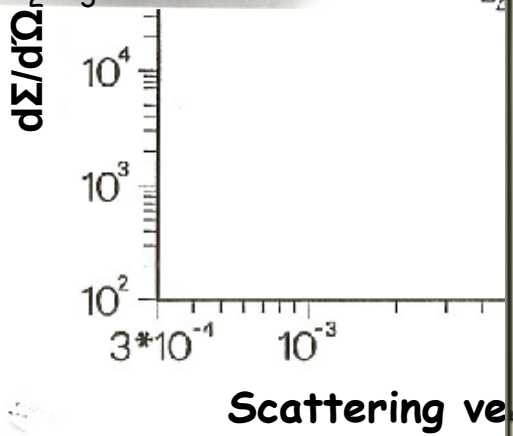
Poren f(σ,ε;T,t)
Voids f(Φ,T,t)
He-Blasen

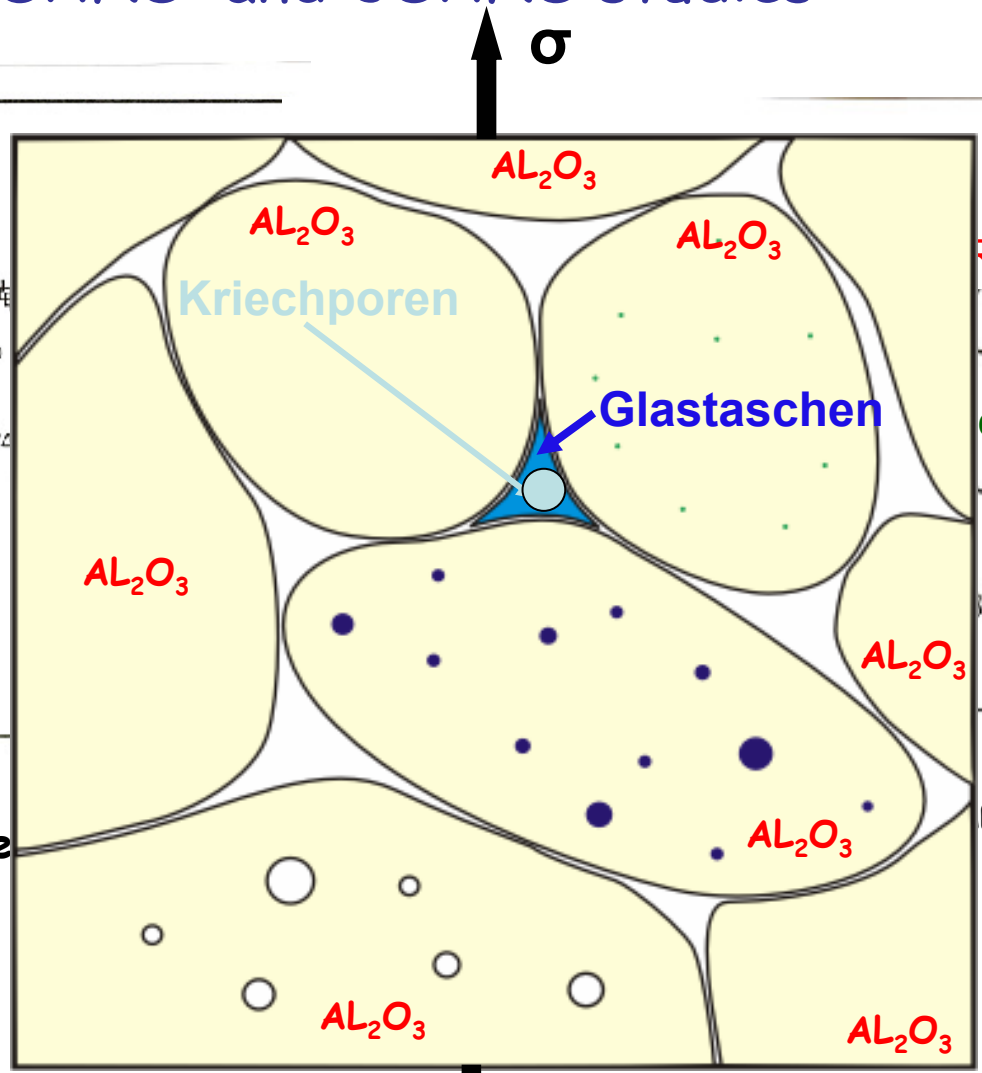
Kriechporen in Fluessig-Phase gesintertem AL_2O_3

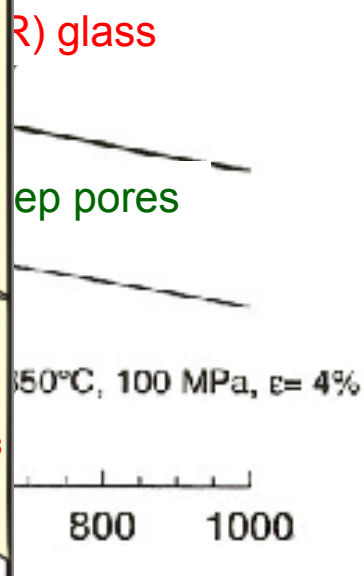
SANS and USANS studies



AL_2O_3 Leitschaufel

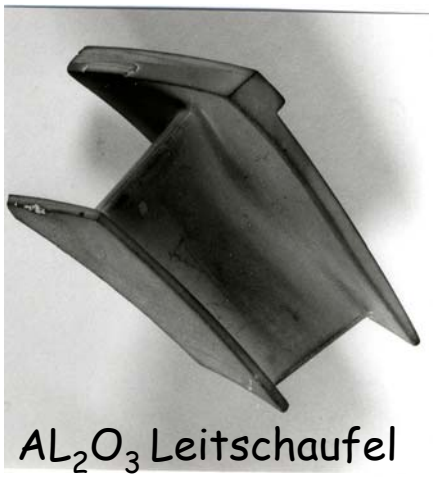






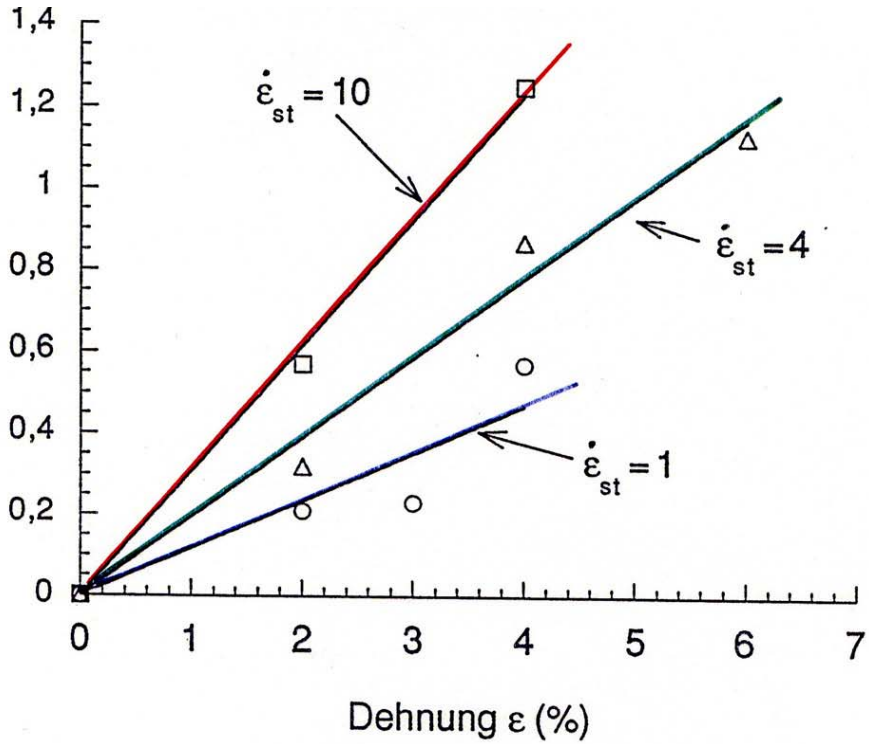
M. Klatt et al.

Kriechporen in Fluessig-Phase gesintertem AL_2O_3



AL_2O_3 Leitschaufel

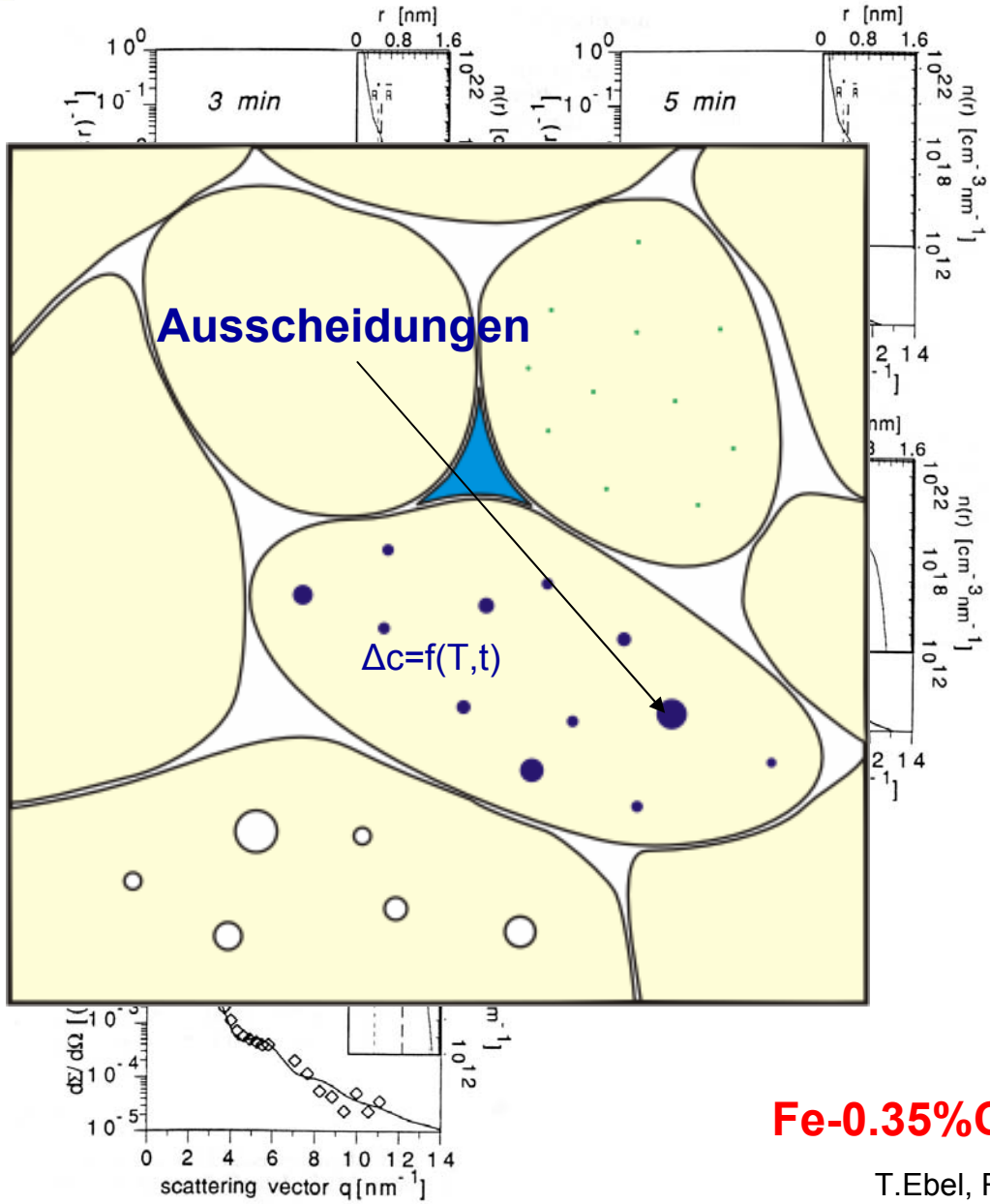
Entwicklung des Porenvolumens f(ε ; dε/dt) %



$$\Rightarrow \quad V_{Pore}(R, \varepsilon) \approx \text{konst.} \cdot \varepsilon \cdot \sqrt{\dot{\varepsilon}_{st}} \cdot V_{Glastaschen}(R)$$

M. Klatt et al.

Ausscheidungskinetik in uebersaettigten Legierungen



Streuquerschnitt

q [1/nm]

Cu-0.8at%Co

T= 490 °C

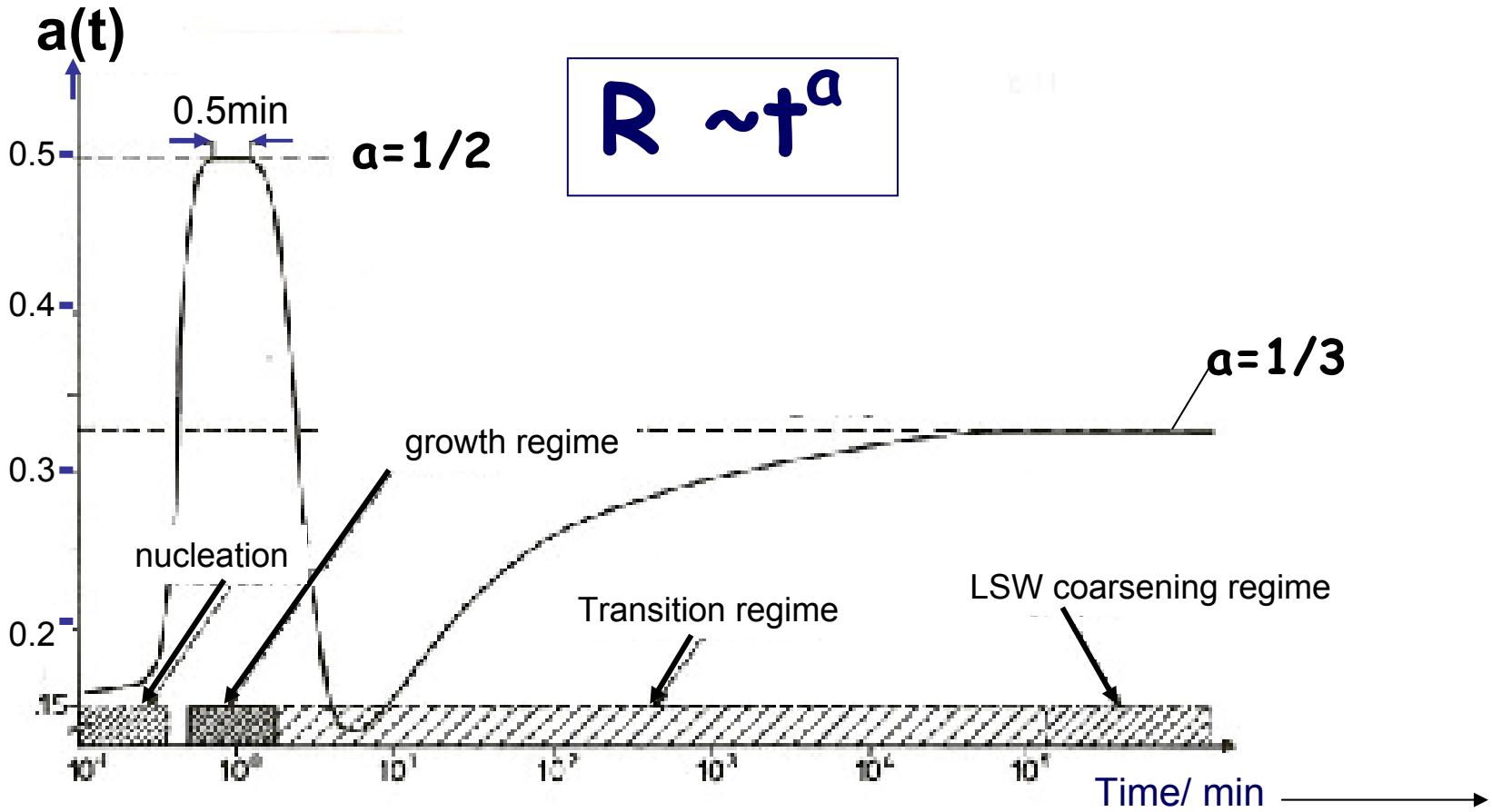
Fe-0.35%Cu; Cu-Ti; Ni-Al

T.Ebel, R.Kampmann, R.Wagner

Decomposition kinetics
-Cluster Dynamics Model-

R.Kampmann, R. Wagner

Cu- 1.9at% Ti ; T= 350 °C



wissen schafft nutzen

Materials for hydrogen storage

GKSS FORSCHUNGSZENTRUM

Hydrogen is considered as an alternative energy carrier for the future…

…and light metal hydrides offer the potential of safest hydrogen storage in a tank

Current challenges:

- **Reduction of operating temperature**
- **Acceleration of kinetics, e.g. with catalysts**

Need to understand the microstructure of the hydrides and structural changes during loading and unloading with H_2

→ **Important contribution by neutron scattering (Hydrogen contrast)**

⇨ In-house research in cooperation with industry

Helmholtz Initiative 'FuncHy: Functional Materials for Mobile Hydrogen Storage'

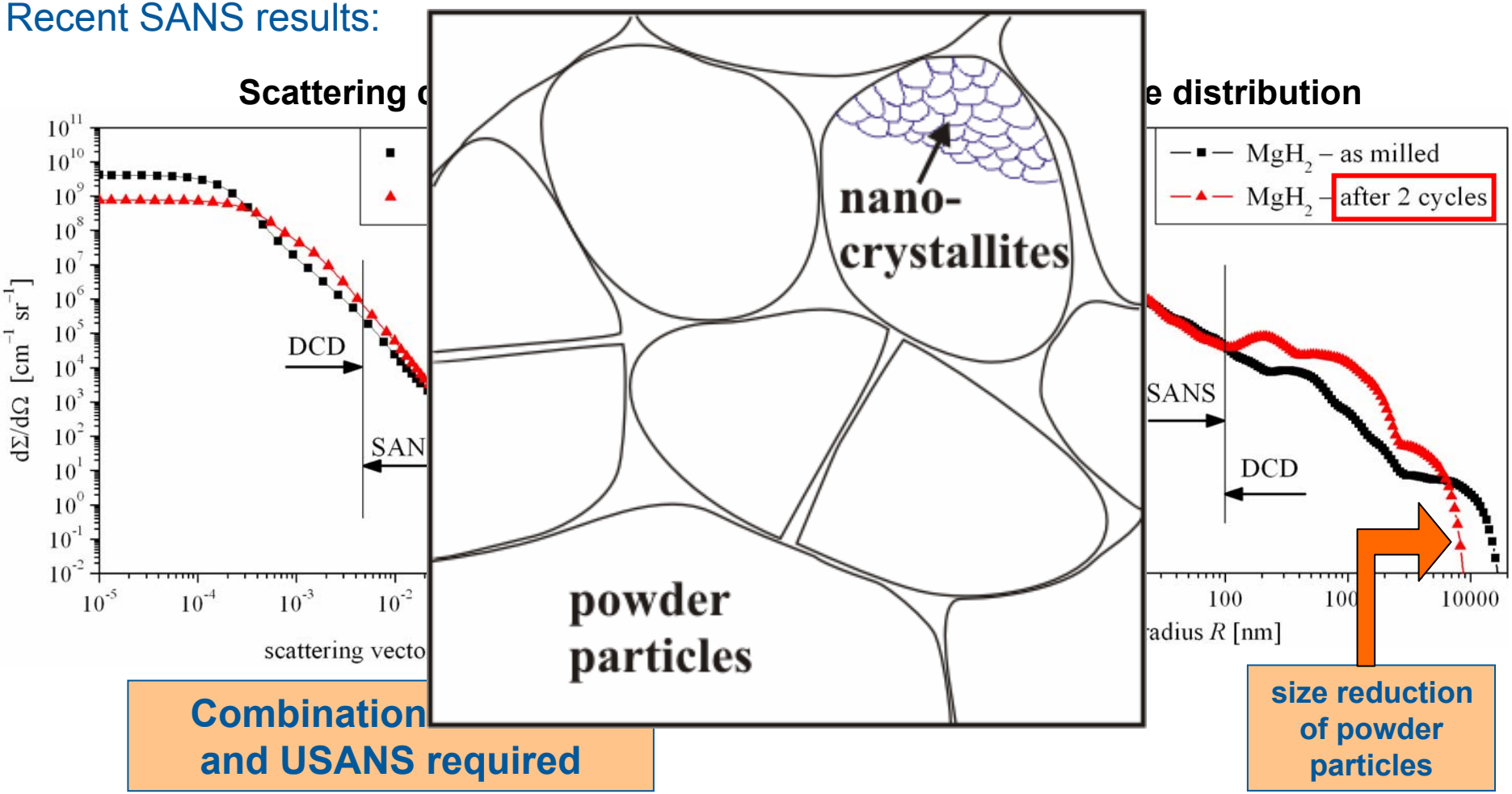
BMW DAIMLER OPEL VW

HELMHOLTZ ASSOCIATION

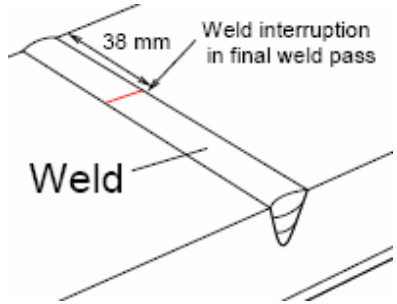
Materials for hydrogen storage

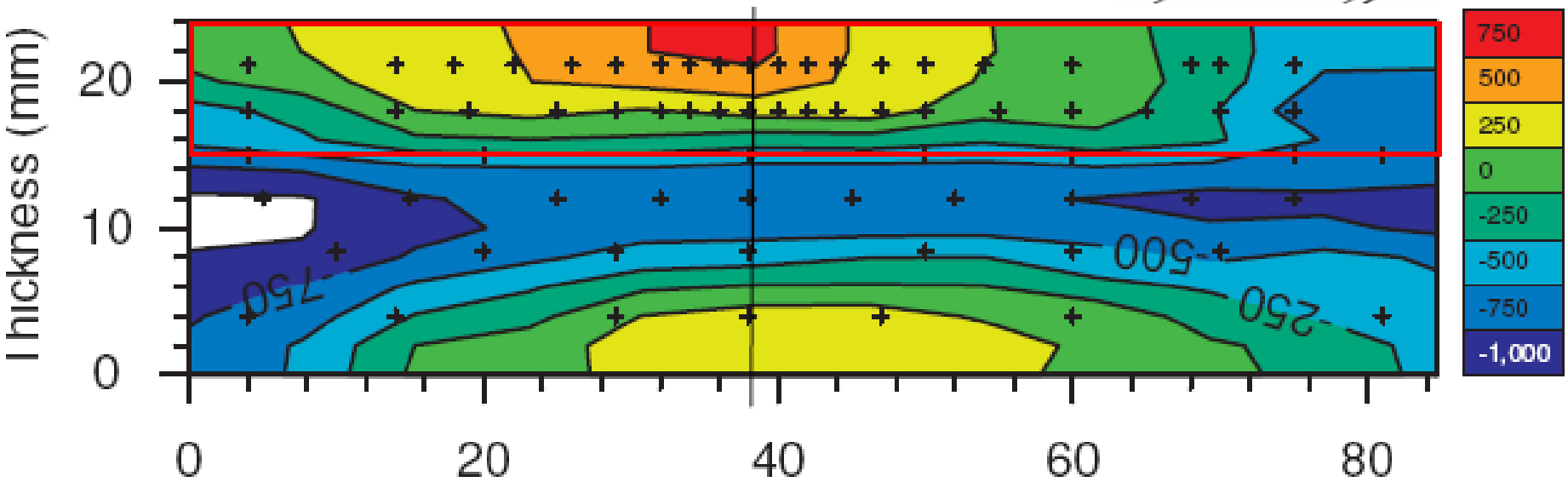
Loading and unloading of Mg powder with H_2 at 300 °C

Recent SANS results:



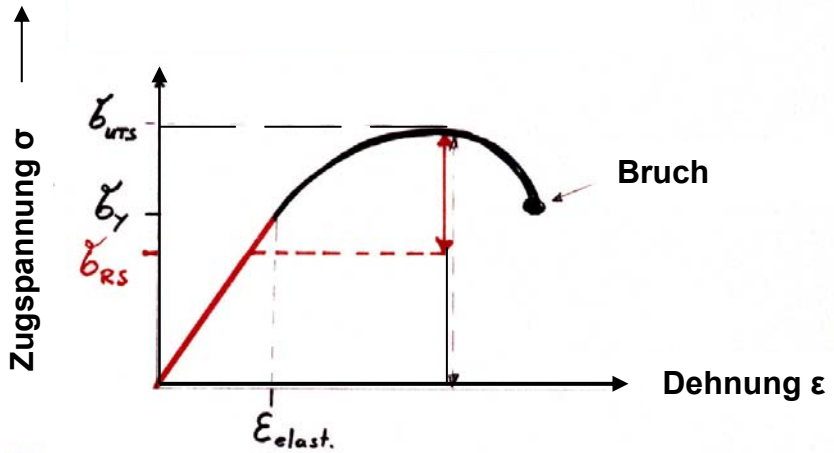
Herstellungstechnologien





M. Turski et al. (Open University, UK)

Eigenspannungsanalysen



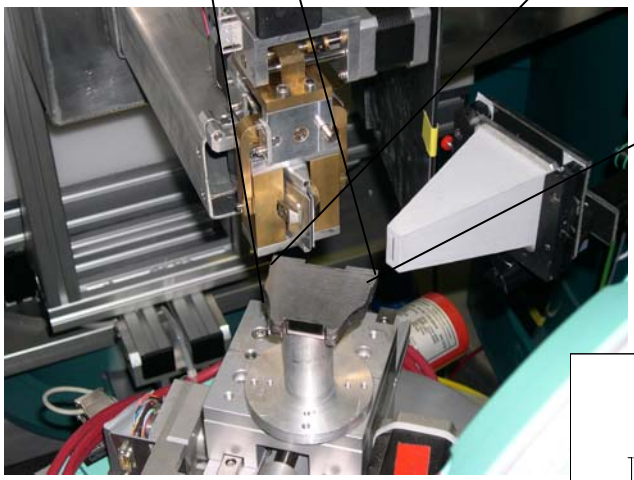
Generalized (isotropic) Hooks' law

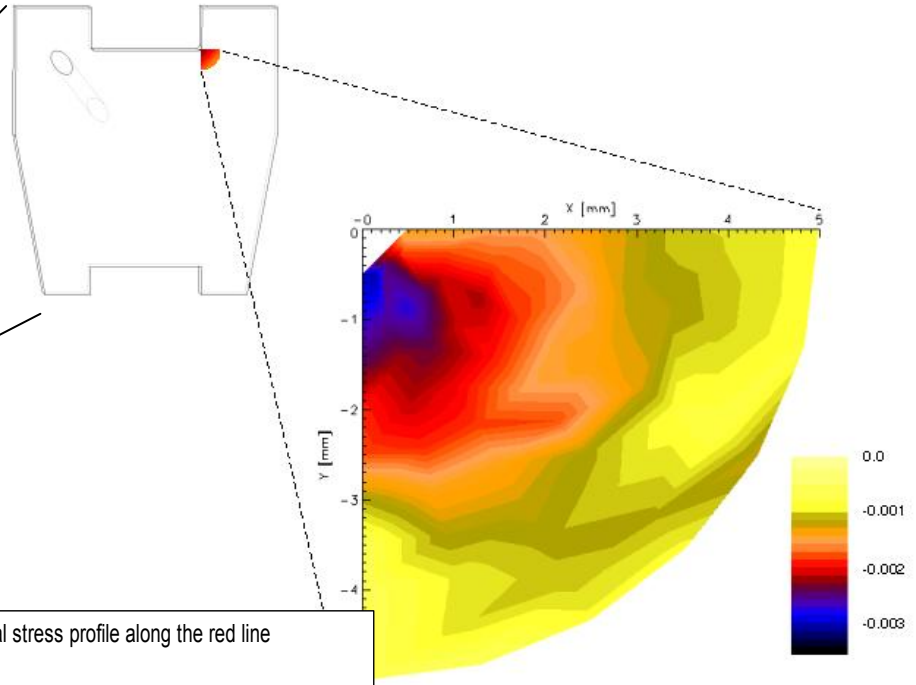
$$\begin{pmatrix} \sigma_1 & 0 & 0 \\ 0 & \sigma_2 & 0 \\ 0 & 0 & \sigma_3 \end{pmatrix} = \frac{E}{1+\nu} \begin{pmatrix} \varepsilon_1 & 0 & 0 \\ 0 & \varepsilon_2 & 0 \\ 0 & 0 & \varepsilon_3 \end{pmatrix} + \frac{\nu E}{(1-2\nu)(1+\nu)} (\varepsilon_1+\varepsilon_2+\varepsilon_3) \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

ε_i : Principle strains

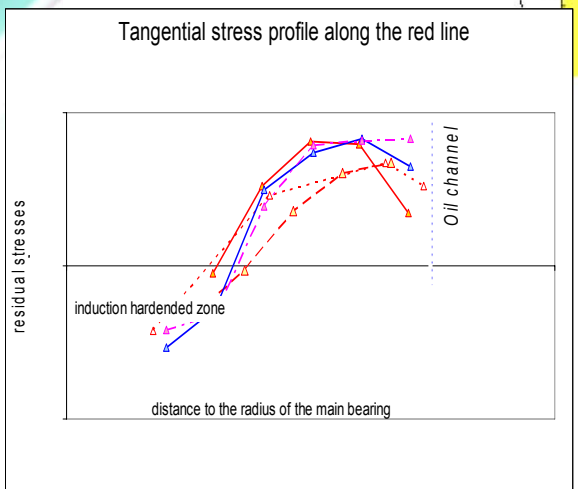
Industrielle Forschung mit Neutronen

Eigenspannungsanalysen in gehaerteten Kurbelwellen





STRESS SPEC @ FRM II



Farb-Code: Verschiedene Druckspannungen

P. Lemke, TU Berlin, M. Hofmann, FRM-II

Industrielle Forschung mit Neutronen

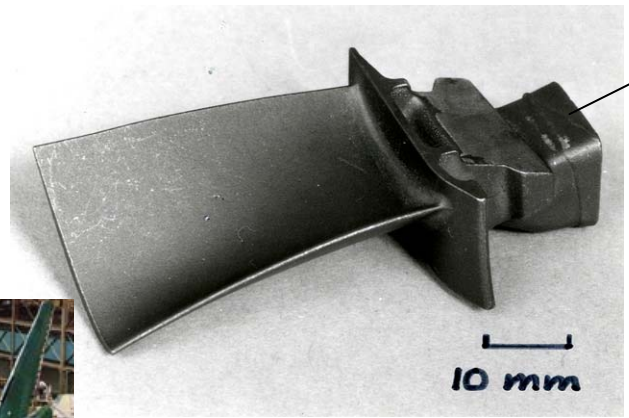
Eigenspannungsanalysen

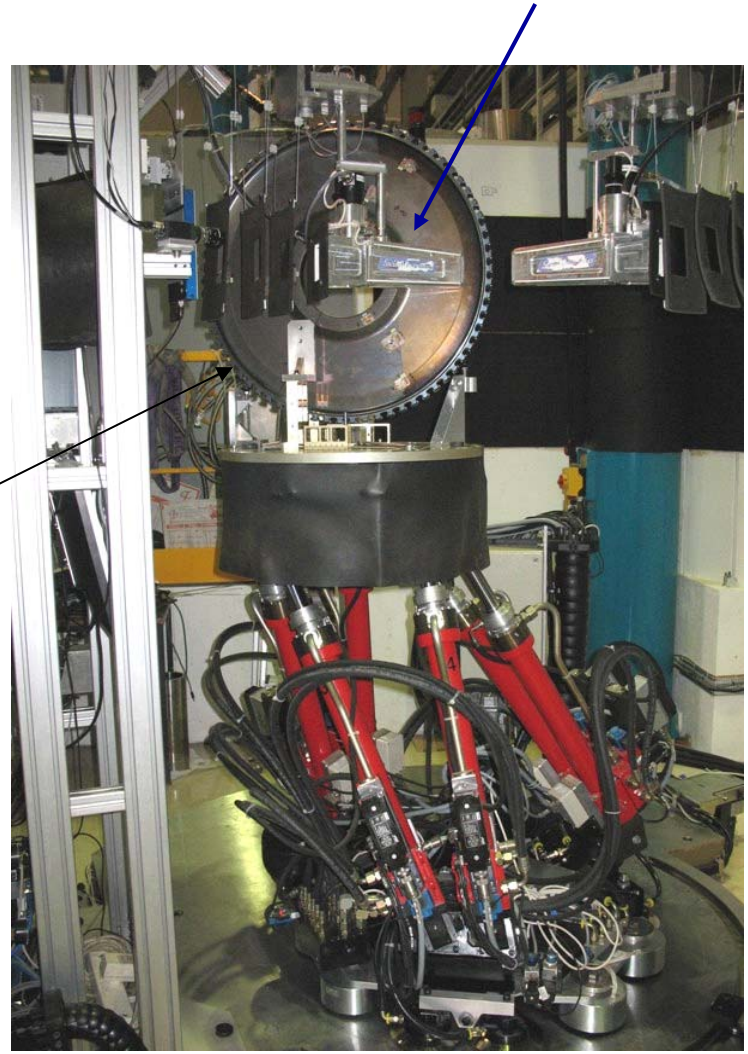
Titan-Flugturbinenscheibe

(franzoes. Hersteller)

700 mm Dmr.

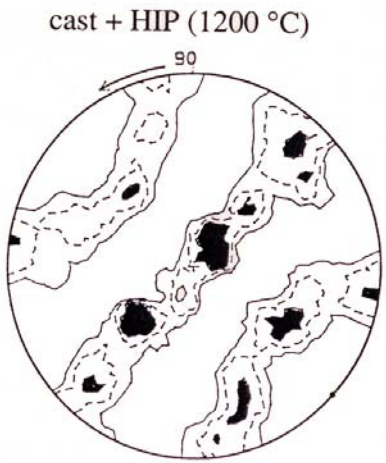
30 kg

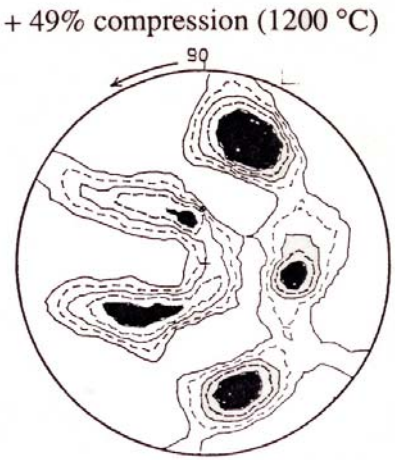




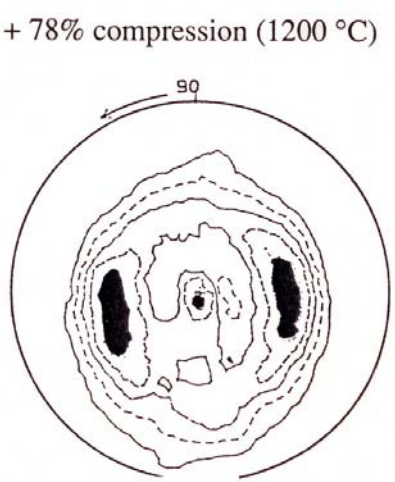
D. Hughes et al./ILL

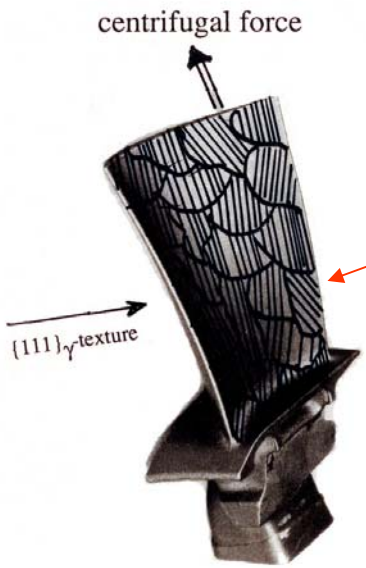
Texturen in intermetallischen γ-TiAl Legierungen





Texturentwicklung nach uniaxialer Stauchung





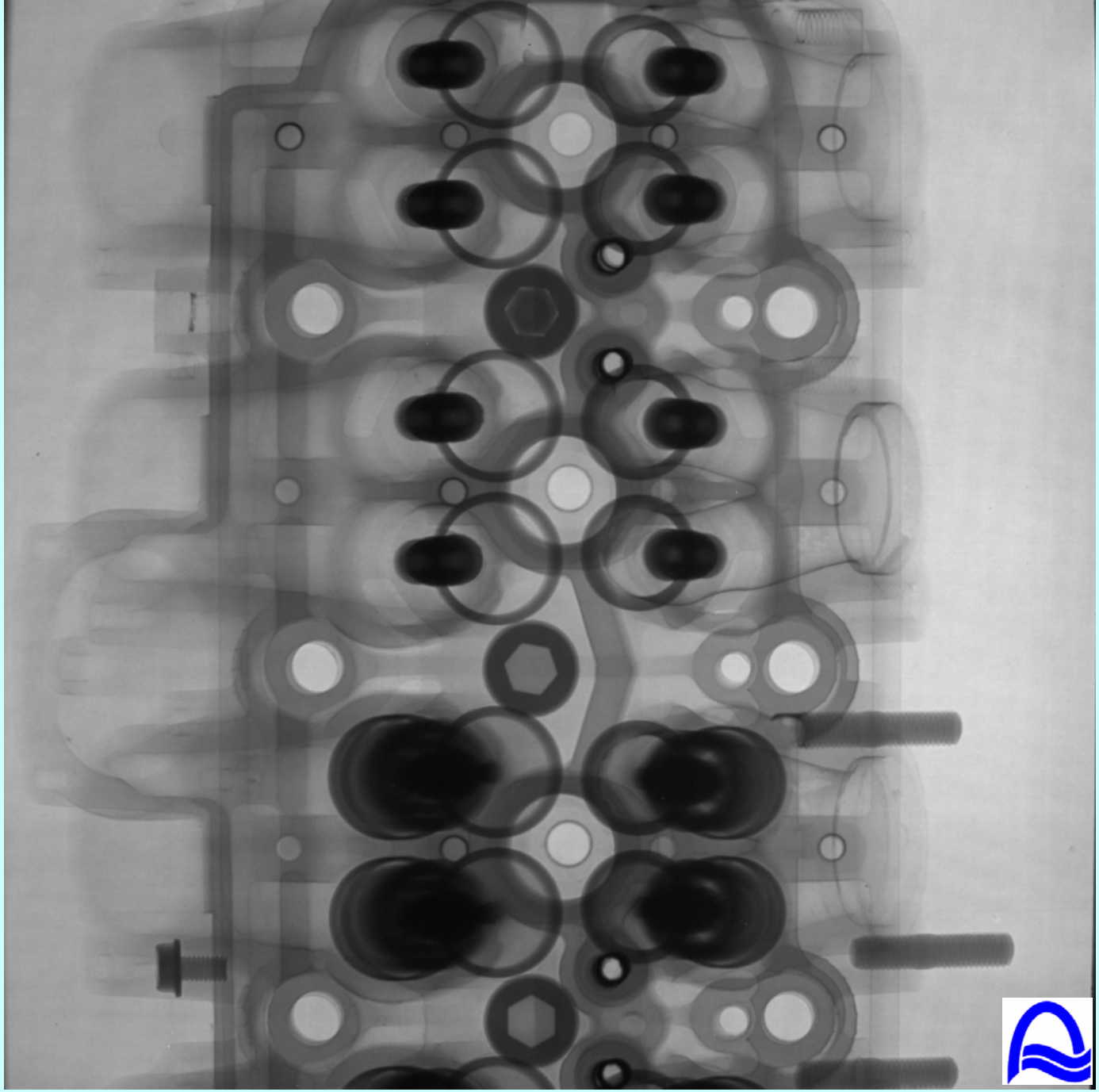
Strangpressen, Formschmieden

H.G;Brokmeier et al.

Zerstoerungsfreie Pruefung

-Neutronentomographie-

Neutronenradiographie
eines 4-Kolben Motors

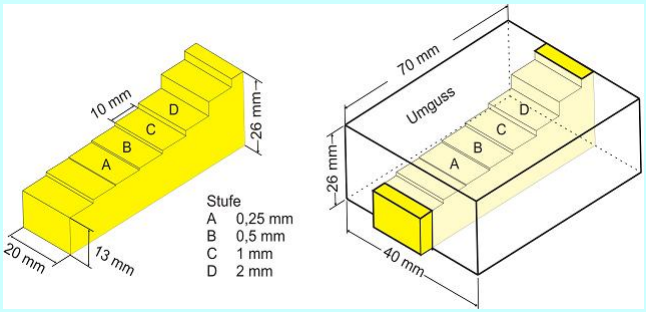


ANTARES @

World Conference on Neutron Radiography, 15.-19.10.2006, Gaithersburg, USA

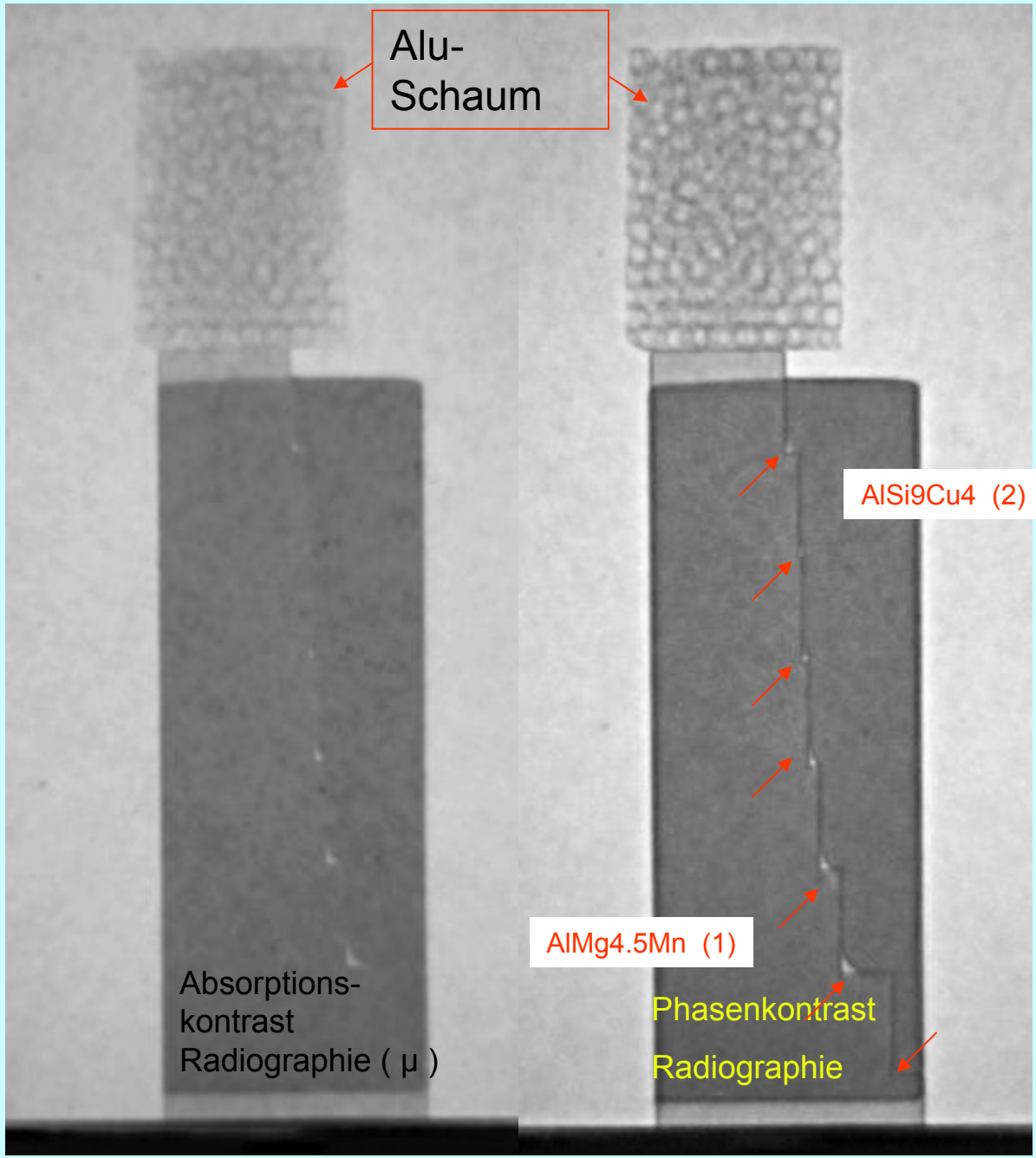
B. Schillinger et al.

Entwicklung der Phasenkontrasttomographie an ANTARES @



Phasenverschiebg.:

$\delta_1 = 1 - Re[n_1] < \delta_2$



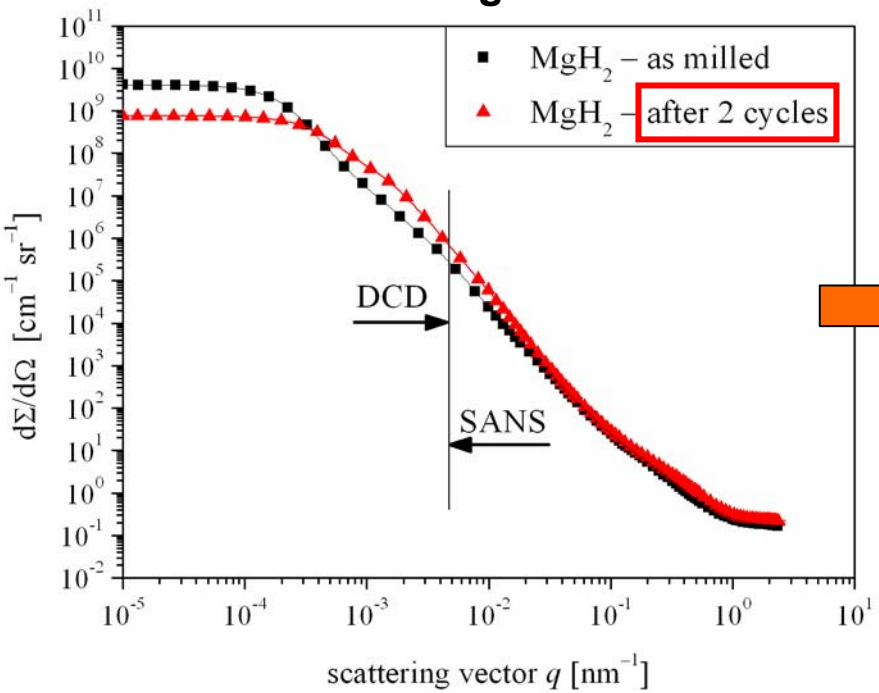

...viel Erfolg fuer die naechsten 50 Jahre.....!
50 Jahre Neutronenforschung in Garching – und deren Zukunft

Materials for hydrogen storage

Loading and unloading of Mg powder with H_2 at 300 °C

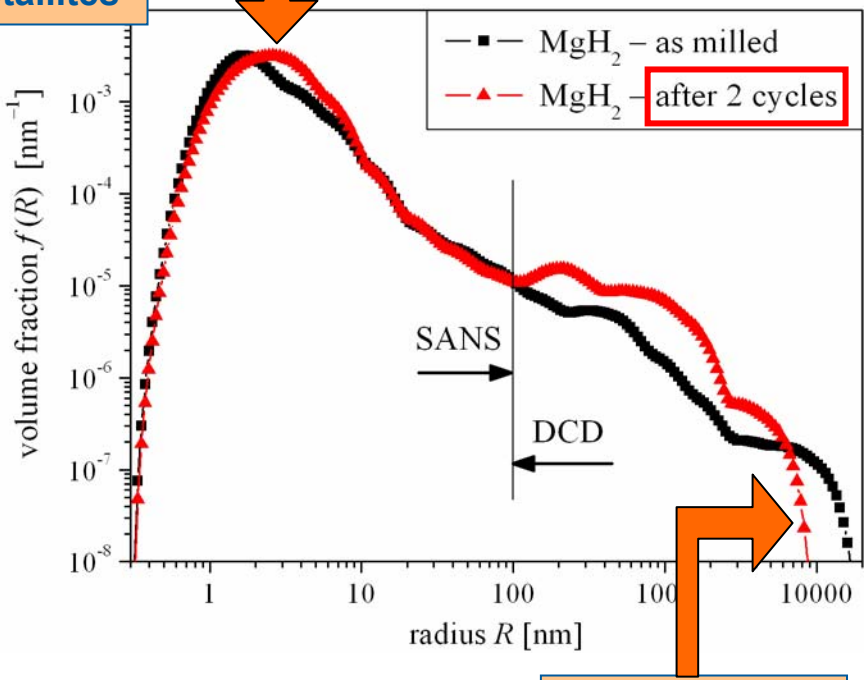
Recent SANS results:

Scattering curve



coarsening of nano-crystallites

Size distribution



Combination of SANS and USANS required

size reduction of powder particles